UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Lithology and stratigraphy of a drill core from the vicinity of the Hack Canyon mines, Mohave County, northern Arizona

by

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Open-File Report 87-0144

1987

[1]Denver, Colorado

ABSTRACT

In March 1980, Western Nuclear, Inc. drilled an exploratory core hole 0.7 miles northwest of the Hack II and III mines in northern Arizona. The core was donated to the U.S. Geological Survey to provide background samples of unaltered, unmineralized rock within the Grand Canyon. The core hole is collared in the Harrisburg Gypsiferous Member of the Kaibab Limestone, trangresses the Kaibab Limestone, the Toroweap Formation and Coconino Sandstone, and bottoms out 21.5 ft into the Hermit Shale; the entire interval is of Lower Permian age.

The Kaibab Limestone interval in the core contains 155.5 ft of the Harrisburg Gypsiferous Member, consisting of grayish-red to very pale-orange, fine-grained sandstone and calcarenite with bluish-white gypsum and 289.5 ft of the Fossil Mountain Member, containing light-gray to white, fossiliferous, cherty limestone with mudstone. The Toroweap Formation in the core consists of 180 ft of interbedded, yellowish-gray to yellowish-orange dolomite, limestone, sandstone, siltstone, and gypsum of the Woods Ranch Member; 200 ft of light-gray to pale-orange, cherty limestone, dolomite, and siltstone of the Brady Canyon Member; and 32 ft of orange to gray, calcareous sandstone and siltstone of the Seligman Member. The Coconino Sandstone in the core is 46.5 ft thick and contains very pale-orange, crossbedded, slightly calcareous, fine-grained sand. The 21.5 ft of Hermit Shale in the core has the characteristic deep red color, thin, flat laminations and small grain size.

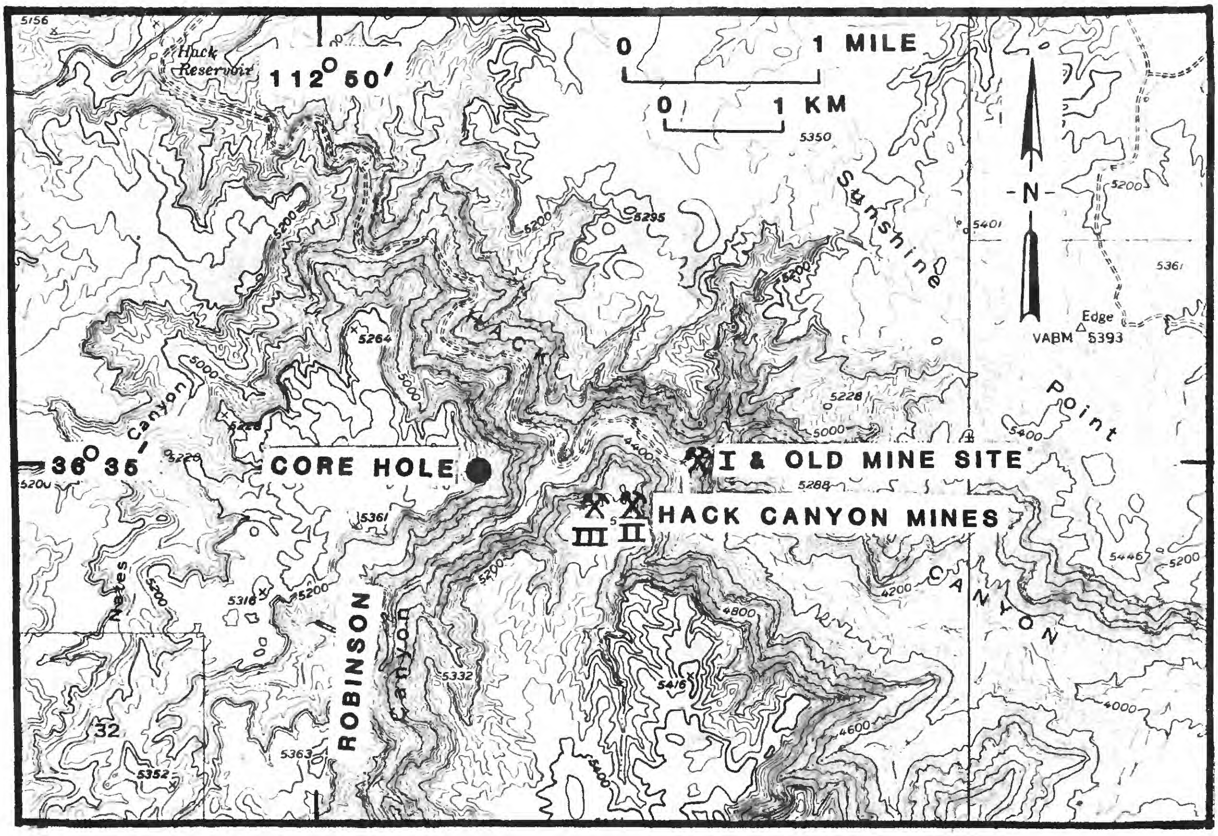
Celadonite occurs persistently throughout the Kaibab Limestone interval of the core as a green stain in very thin, wispy clay laminations, and is not found elsewhere in the core. A 2-inch thick layer of pale blue translucent anhydrite occurs at a depth of 166 ft in the core; the rare coloration probably represents a lattice defect. Trace amounts of scattered, very finely disseminated pyrite and marcasite are present in most of the calcareous and fine-grained units in the core; the only significant concentration occurs within thin pods and veins at 156 ft. Geothite is scattered throughout the core as small pods (diameters <0.2 inches), with one larger concentration inside a single vug at 492.5 ft.

INTRODUCTION

In March 1980 Western Nuclear, Inc. drilled an exploratory core hole 0.7 miles northwest of Hack II and III mines in northern Arizona (fig. 1). The drill site was located on a promontory at the intersection of Robinson Canyon and Hack Canyon. The core was donated to the U.S. Geological Survey (USGS) in 1984 to provide background lithologic and stratigraphic data for the Grand Canyon region. The core has been studied by the USGS and several mining companies for comparison with the jumbled rock found within breccia pipes. This lithologic log (Appendix A) was particularly useful for comparison with core and chip samples from drilling on the Hualapai Indian Reservation. The core is stored in the USGS core storage laboratory in Denver and is available to the public for study.

The core hole is collared in red beds of the Harrisburg Gypsiferous Member of the Kaibab Limestone, transgresses the Kaibab Limestone, the Toroweap Formation and Coconino Sandstone, and bottoms out 21.5 ft into the Hermit Shale (fig. 2). All of these formations are of Lower Permian age.

Breccia pipes and other collapse features occur throughout the area (Wenrich, 1985). Although this core hole penetrated unaltered, unbrecciated rock that does not appear to be inside or immediately adjacent to a breccia



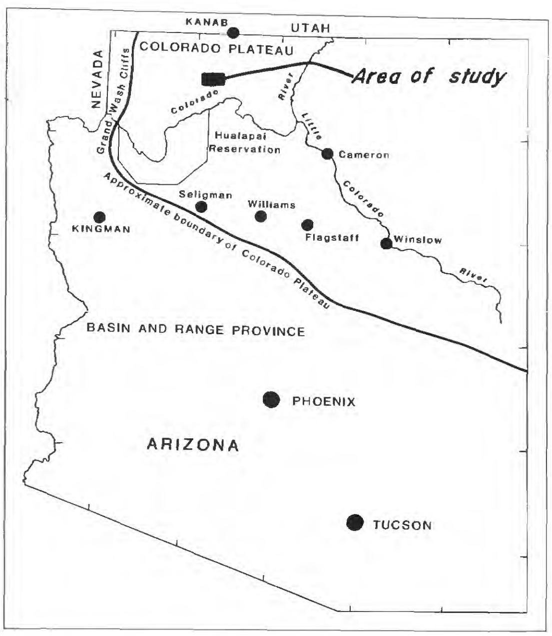


Figure 1--Location map showing the location of the core hole, the Hack Canyon mines, Hack Canyon, and Robinson Canyon. Topographic location map is taken from the Heaton Knolls quadrangle, scale 1:62,500.

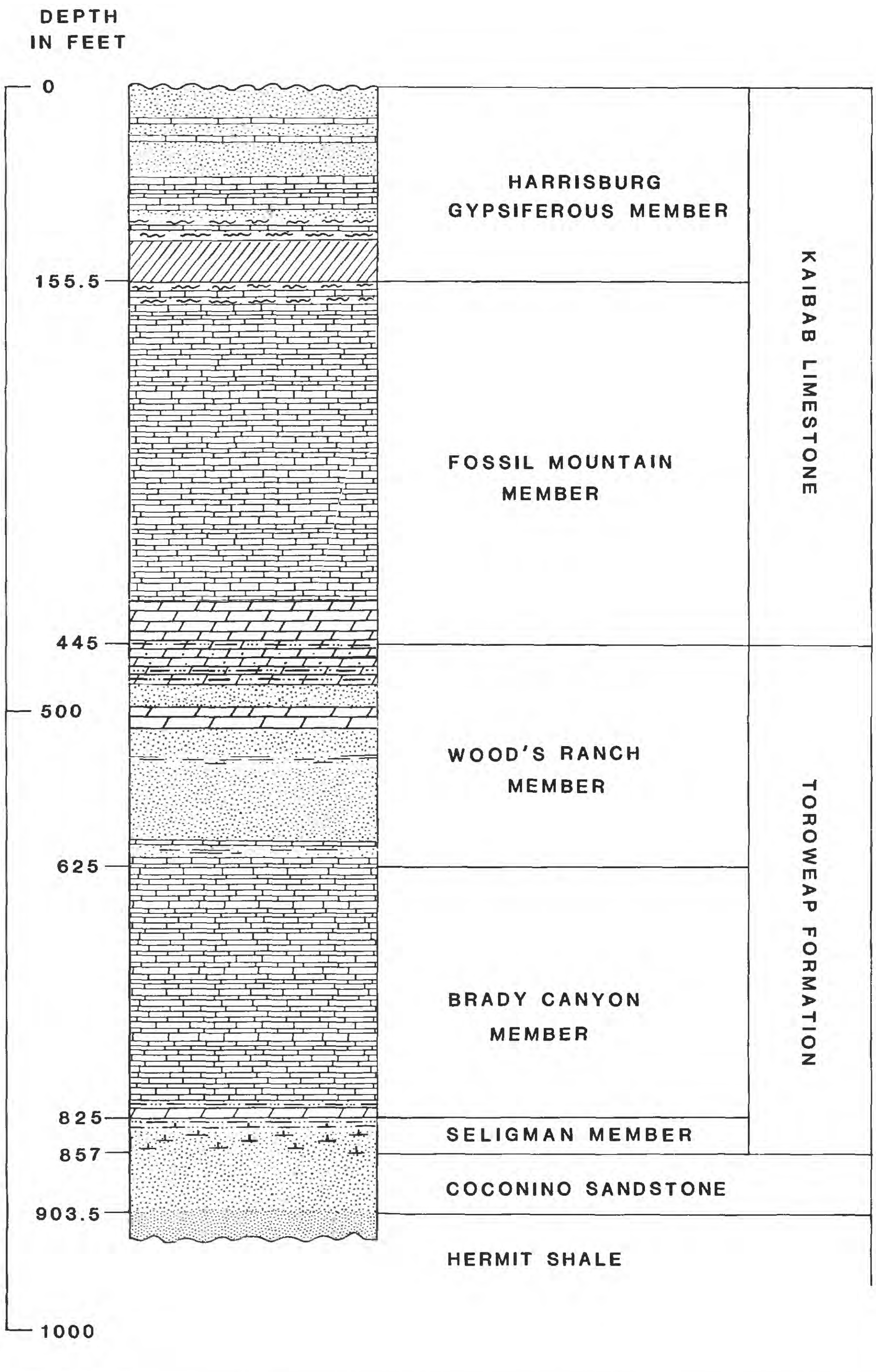


Figure 2--Stratigraphic column showing rock units transgressed by the core drilled near the Hack Canyon mines. Depths and lithologies shown are taken from the lithologic description of the core.

pipe, it is in the proximity of three active mines. Mining within the nearby Hack Canyon I, II, and III mines is exploiting uranium deposits within breccia pipes. Although present mining operations are not removing any byproduct metals, they could include: Ag, Co, Cu, Ni, Pb, and Zn if prices for these metals rise in the future.

This report provides (1) a detailed lithologic description of the core (Appendix A); (2) a discussion on the location of the formation and member boundaries; and (3) notes on the observed mineralized rock. Samples were submitted for geochemical and isotope analysis, and will be summarized in a later report. Drilling data for the hole are shown below:

Inclination	-70°
Bearing	N68°E
Length	925 ft
True Depth	852 ft
Size	HQWL
Drilling company	Longyear
Collar Elevation	5,247 ft above sea level
Date Drilled	March 25, 1980
Location	NW ¼ Section 27, T37N, R5W
Latitude, Longitude	36°35'00", 112°49'07"

GEOLOGIC SETTING

Hack and Robinson Canyons are located about 15 miles north of the central part of the Grand Canyon, Arizona; they typify the dissection within the Colorado Plateau province. Lower Permian rocks are exposed in the canyon walls near the drill site, with the Harrisburg Gypsiferous Member of the Kaibab Limestone capping the canyon rims and the Hermit Shale exposed along the canyon floors. The underlying Permian/Pennsylvanian Esplanade Sandstone crops out downstream near the mouth of Hack Canyon. The local bedding is subhorizontal.

FORMATION AND MEMBER CONTACTS

The present plateau surface at the drill site lies about 125 ft below the contact of the Kaibab Limestone with the overlying Moenkopi Formation (George Billingsley, personal communication, 1985). The Harrisburg Gypsiferous Member of the Kaibab Limestone is the topmost Paleozoic unit in the Grand Canyon region. The member consists of slope-forming sequences of sandstone, mudstone, carbonates, and gypsum beds (Billingsley, 1978). The contact of the Harrisburg Gypsiferous Member with the underlying Fossil Mountain Member was located where fossiliferous, cherty limestone becomes the predominant facies at 155.5 ft. The calcareous mudstone at 155.5-156.5 ft appears to be a transitional unit and could justifiably be placed within the Harrisburg Gypsiferous Member. The Fossil Mountain Member (155.5-445 ft) forms a resistant cliff in outcrop and represents a westerly transgression of the Kaibab sea across the region (McKee, 1938).

The Kaibab Limestone rests uncomformably on top of the Toroweap Formation, with chert fragments and disturbed bedding occurring just above the contact in the core. The Woods Ranch Member of the Toroweap (445-625 ft), in which chert is absent, contains abundant gypsum and sand in greater proportions than the Fossil Mountain Member of the Kaibab Limestone. The Woods Ranch Member is slope-forming and represents the regression and evaporation of the Toroweap sea (McKee, 1938).

The Brady Canyon Member of the Toroweap Formation (625-836.5 ft) forms a cliff and was defined in the core by the appearance of chert nodules and a decrease in sand content from the overlying Woods Ranch Member. This entire unit is finer grained than the Woods Ranch Member.

The Seligman Member of the Toroweap Formation (825-857 ft) is a calcareous sandstone representing a transgression of the sea from the west (McKee, 1938). According to Billingsley (1978) the sandstones of the Seligman Member grade upward into a "sandy siltstone and mudstone slope with interbedded carbonates and gypsum". In the drill core, just below the contact between the Brady Canyon and Seligman Members is 10 ft of siltstone, which overlies a 1.5 ft thick dolomite bed (835-836.5 ft). The contact was placed at the top of this transitional zone [as described by Billingsley (1978)] between the carbonates of the Brady Canyon Member and the calcareous sandstones of the Seligman Member.

The cliff-forming Coconino Sandstone (857-903.5 ft) was distinguished from the sandstone of the Seligman Member of the Toroweap Formation by its relatively less calcareous matrix and visible cross-bedding. The Coconino Sandstone has been interpreted to be an aeolian deposit, based on outcrop containing low-relief, wind ripple marks (McKee, 1933).

The Hermit Shale (903.5-925 ft) is identifiable by its deep red color, fissile siltstones and very fine-grained sandstones. The unit at 903.5-908.5 ft is very fine-grained with flat, thin laminations, and is believed to be bleached Hermit Shale rather than Coconino Sandstone. In outcrop, the Hermit Shale forms soft, dark-red slopes below the Coconino Sandstone cliff, and is about 650 ft thick in this area (thickness from George Billingsley, personal communication, 1985). White (1929) proposed that the deposition of the Hermit Shale occurred in a wide lowland river flood plain.

MINERALIZATION

The most noteable effect of mineralization in this core is the presence of celadonite $[K(Mg,Fe^{2+})(Fe^{3+},Al)Si_4O_{10}(OH)_2]$ that is persistent throughout most of the Kaibab Limestone interval of the core (most abundant in the Harrisburg Gypsiferous Member). The celadonite occurs in green-stained, very thin, wispy clay laminations. The mineral was identified by X-ray diffraction as celadonite or glauconite $[(K,Na)(Al,Fe^{3+},Mg)_2(Al,Si)_4O_{10}(OH)_2]$, which have nearly identical compositions and properties (Deer and others, 1962a) and are indistinguishable by X-ray diffraction patterns (Chen, 1977). Glauconite is a clay alteration product that forms in a reduced marine environment during times of slow deposition, forming globular pellets or staining sand grains (Grim, 1968). Celadonite forms as a secondary mineral associated with the alteration of intermediate to basaltic volcanic rocks (Roberts and others, 1974). The vein-like appearance of the green staining in the core suggests secondary fluid movement deposited the mineral rather than the settling of suspended particles. Thus, the green mineral present is probably celadonite. Celadonite was found only in the Kaibab Limestone interval of the core, which may provide a regional characteristic of the formation.

A 2-inch thick layer of pale-blue anhydrite and gypsum occurs at a depth of 166 feet in the core. The layer is translucent with nearly perfect cleavage. The rare, pale-blue color probably represents a lattice defect in the mineral's structure (Peter Modreski, USGS., personal communication, 1985). According to Deer and others (1962b), the blue color in some samples is thought to be the result of natural radiation. Yet, no anomalous internal radiation is present in rock adjacent to the layer (gamma counts averaged only 7 cps). An external radiation source is unexpected, with the nearest known uranium deposit being Hack III mine, 0.7 mile to the southeast.

Trace amounts of scattered, very finely-disseminated pyrite can be observed under magnification (binocular microscope) in most of the calcareous and fine-grained units within the core. The only significant concentration of pyrite is found at 151.5 and 156 ft (bounding the contact of the Harrisburg Gypsiferous and Fossil Mountain Members) as pods and veins, 0.1- to 0.8-inches thick. Within these pods and veins the normal dolomite matrix has been replaced by an anhedral intergrowth of pyrite and marcasite. Interestingly, this texture and intergrowth is similar to that found within breccia pipe orebodies, except for the absence of barite and Cu-, Zn-, Ni-, and Co-sulfides in this core. Trace amounts of pyrite are present in thin mudstone stringers and partings (168-173 ft).

Occurrences of goethite are very minor and scattered throughout the core. Pods of goethite in the core are generally less than 0.2-inch in diameter. One larger concentration of goethite crystals occurs in a single large vug at 492.5 ft (Woods Ranch Member). The crystals inside the vug reach 0.3-inch in length and are associated with calcite crystals and massive limonite.

Alteration products and secondary minerals such as goethite, celadonite, and pyrite are believed to be possible pathfinders for mineralized breccia pipes. Nevertheless, these minerals are present in minor amounts within this core drilled from unmineralized, unaltered rock, presumably located away from any breccia pipe. Goethite is known to occur throughout surface outcroppings of the Kaibab Limestone in northern Arizona. In general though, outcrops of Kaibab above known breccia pipes appear to have significantly greater concentrations of goethite concretions. Celadonite is commonly found in the Harrisburg Gypsiferous Member of the Kaibab Limestone, although it may be slightly more concentrated in this unit when located above a breccia pipe. At present it is not clear how reliable these three minerals are as indicators for mineralized breccia pipes. Certainly pyrite is the best indicator of the three and goethite is second. If indeed no breccia pipes are adjacent to this drill hole, then pyrite, goethite, and celadonite should only be used as a pathfinder when they are present in concentrations significantly greater than in this drill core.

ACKNOWLEDGEMENTS

The authors wish to thank Western Nuclear, Inc. for their generous donation of the core and for transporting it from Kanab, Utah to Denver. The core has provided beneficial data for our research in the region. Also, thanks go to George Billingsley for his expert stratigraphic consulting and manuscript suggestions. Thanks also to Richard Balcer for his preliminary descriptions.

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APPENDIX A

LITHOLOGIC DESCRIPTION OF HACK CANYON CORE

<u>Depth in feet</u>

Harrisburg Gypsiferous Member of Kaibab Limestone (0 - 155.5)

0 - 21.5	Sandstone; pale-red to pinkish-gray, fine-grained, well-sorted, calcareous, very thinly laminated; includes abundant patches of vuggy, fossiliferous, calcareous mud with gypsum crystals and patches of celadonitic clay; soft-sediment deformation around calcareous zones
21.5 - 28.5	Sandstone; grayish-red to moderate red, fine-grained, well to moderately well-sorted, thinly laminated, calcareous, micaceous; includes soft-sediment deformation with rip-up clasts and thin celadonitic clay laminae
28.5 - 30	Calcarenite; very pale-orange, moderately well-sorted, very calcerous, vuggy; replacement with gypsum crystals in vuggy zones; includes thin celadonitic clay laminae
30 - 36	Sandstone; moderate-red to grayish-red, fine-grained, moderately well-sorted, calcareous, thinly laminated; includes abundant soft-sediment deformation with rip-up clasts; very thin celadonitic clay laminae
36 - 40.5	Calcarenite; very pale-orange with thin moderate-pink, hematitic streaks, thinly laminated; includes thin celadonitic clay laminae. Upper 1 foot is thick-bedded
40.5 - 55	Sandstone; moderate-red to pinkish-gray, fine-grained, moderately well-sorted, thinly laminated; includes abundant soft-sediment deformation with rip-up clasts and thin celadonitic clay laminae
55 - 69	Interbedded sandstone and siltstone; sandstone is pale-yellowish-orange, fine- to coarse-grained, poorly sorted, subrounded grains, thinly laminated to thick bedded; includes soft-sediment deformation and thin celadonitic clay laminae. Siltstone is yellowish-gray. Entire unit is clayey, mottled, with hematite alteration
69 - 95	Calcarenite to calcareous claystone; unit is very light-gray with light-gray chert clasts; includes grayish-orange-pink laminae; very vuggy zones with coarse chert fragments; thin celadonitic clay laminae
95 - 115	Calcarenite, mudstone, and medium-grained sandstone; entire unit is very pale-orange, well-sorted, very clayey, calcareous, mottled; includes cherty zones; minor hematite alteration; abundant soft-sediment deformation in upper 6 ft and lower 3 ft; abundant thin celadonitic clay laminae in upper 6 ft
115 - 120	Mudstone (possibly altered limestone); pale yellowish-orange, very calcareous, thick-bedded, poorly consolidated; includes minor, thin, celadonitic clay laminae
120 - 136	Gypsum and interbedded mudstone; gypsum is bluish-white. Mudstone is very light-gray, very well-sorted,

	calcareous, mottled; includes sandy laminations, soft-sediment deformation, and gypsum crystals in laminae
136 - 145	Interbedded gypsum and siltstone; gypsum is bluish-white and thick-bedded. Siltstone is pale-red, calcareous, mottled, bleached to pinkish-gray in lower 2 ft
145 - 155.5	Gypsum; bluish-white, calcareous, mottled; includes minor celadonitic and pinkish-gray clay laminae. At 151.5 ft, a medium dark gray pod, 0.8-inches thick, contains disseminated massive pyrite and marcasite and cubic pyrite crystals

Fossil Mountain Member of Kaibab Limestone (155.5 - 445)

155.5 - 156.5	Mudstone; light-gray, calcareous, mottled; includes disseminated pyrite and marcasite within medium-dark-gray pods and veins 0.1- to 0.4-inches thick, dolomitic cement, minor thin celadonitic clay laminae, soft-sediment deformation, trace calcite, and thin wispy light-gray clay laminae containing very finely disseminated pyrite
156.5 - 165	Limestone; light-gray, micritic, recrystallized, mottled; includes calcite crystals on fracture surfaces, bivalves and other fossils, minor celadonitic clay laminae, thin wispy light-gray clay laminae; especially mottled in lower 1.5 ft; scattered goethite.
165 - 168	Mudstone; white, calcareous, very thinly laminated; includes veinlets of calcite crystals and soft-sediment deformation. A 2-inch thick layer of pale-blue anhydrite and gypsum is located at 166 ft
168 - 411	Limestone; white with light-gray mudstone partings, micritic, silty, massive, mottled; includes minor recrystallization, chert nodules, and thin mudstone stringers containing finely disseminated pyrite (probably mixed with marcasite, as at 156 ft) in upper 5 ft, bivalves and other fossils, lenses of fossil hash with gastropods, bryzoans, and sponges; very minor celadonitic clay laminae; minor gypsum crystals in clay partings; mudstone with calcite and gypsum crystals coat fracture surfaces; vugs are scattered and filled with calcite crystals; scattered goethite crystals and pods less than 0.2-inch in diameter. Mudstone partings are especially abundant at 171-172 ft and contain finely disseminated pyrite
411 - 445	Dolomite; yellowish-gray, micritic, vuggy; includes calcareous blotches of fossil hash, chert fragments, and minor calcite crystals. Gradational contact with unit above. Abundant, angular, chert fragments and mottled in lower 7 ft

Woods Ranch Member of Toroweap Formation (445 - 625)

445 - 477	Dolomite; yellowish-gray, very silty, micritic, mottled, thick-bedded, vuggy; includes oolite-rich partings, gypsum crystals in vugs. At 450-463 ft interbedded with

	very pale-orange, silty, calcareous, poorly cemented sandstone lenses
477 - 500	Interbedded dolomite and sandstone; dolomite is yellowish-gray, micritic, thick-bedded, and mottled. Sandstone is grayish-orange, very fine-grained, calcareous, thick-bedded, poorly cemented, vuggy. At 492.5 ft, a vug is filled with calcite and goethite crystals up to 0.3 inch long, plus massive limonite
500 - 510	Dolomite; olive-gray to yellowish-gray, micritic, recrystallized, very vuggy; contains calcite in vugs
510 - 527	Sandstone; very pale-orange, medium- to fine-grained, calcareous, silty; includes gypsum veins, hematitically-altered grains, and calcareous cement. At 525-527 ft, unit is gypsum-rich with thin, pale-red, hematitically-altered laminae
527 - 533	Core was not recovered within this interval
533 - 538	Siltstone; yellowish-gray, calcareous, thick-bedded; includes thin gypsum laminae (only 1 ft of core was recovered in this interval)
538 - 540	Gypsum; white; includes minor clay laminae
540 - 560	Missing core. Loose sand collected is pale yellowish-orange and very fine-grained
560 - 575	Sandstone with interbedded thin limestone lenses; sandstone is pale yellowish-orange, very fine-grained, silty, very calcareous and thick-bedded. Limestone lenses are very light-gray, moderately well-sorted, and limonite-stained
575 - 576	Solution breccia, Iron-stained; includes grayish-red, dark-yellowish-orange, and pale-yellowish-orange fragments in a very fine-grained sandy matrix
576 - 601	Sandstone with thin interbedded limestone lenses; sandstone is pale-yellowish-orange, silty, calcareous, moderately to poorly cemented; contains minor hematitically-altered grains and minor dark opaques. Limestone lenses are very light-gray and silty
601 - 608	Interbedded limestone and siltstone; limestone is very light-gray, fossiliferous, silty; includes vugs due to dissolved oolites. Siltstone is pale-yellowish-orange, very calcareous, sandy, and thick-bedded
608 - 609	Siltstone; pale-yellowish-orange, calcareous, and finely laminated
609 - 625	Limestone; very light-gray, fossiliferous, vuggy; includes vugs filled with white crystals (calcite?)

Brady Canyon Member of Toroweap Formation (625 - 825)

625 - 815	Limestone; very light-gray, vuggy, fossiliferous; porosity varies; includes chert nodules, vugs filled with calcite crystals, and minor, thin, siltstone laminae
815 - 821	Siltstone; very pale-orange, calcareous, slightly sandy; includes vugs filled with quartz crystals, dickite (kaolin group), and kaolinite; calcareous laminae

821 - 825	Dolomite; light-gray to grayish-black, organic-rich, slightly sandy

Seligman Member of Toroweap Formation (825 - 857)

825 - 833	Siltstone; yellowish-gray, very calcareous, very thinly laminated
833 - 835	Siltstone; pale-yellowish-orange to yellowish-gray, very calcareous, very thinly laminated
835 - 836.5	Dolomite; yellowish-gray, very silty; includes thin, convoluted laminae; veins of grayish-pink and white gypsum; thin, fine-grained sandstone laminae; and calcite crystals coating fracture surfaces
836.5 - 837.5	Sandstone; grayish-orange, coarse-grained, well-sorted, very calcareous, cross-bedded; quartz grains are frosted and subangular
837.5 - 857	Sandstone; pale-yellowish-orange to grayish-orange, medium-grained, well-sorted, calcareous, laminated; angular to subangular quartz grains

Coconino Sandstone (857 - 903.5)

857 - 903.5	Sandstone; very pale-orange to pale-yellowish-orange, medium- to fine-grained, slightly calcareous, silty, well-sorted; includes small scale cross-bedding, minor limonite-staining, and frosted, subangular quartz grains. Grayish-orange-pink coating at 875-877 ft

Hermit Shale (903.5 - bottom)

903.5 - 908.5	Sandstone; very light-gray, very fine-grained, noncalcareous, very well-sorted, silty; contains flat, thin laminations. Color change gradational with unit below
908.5 - 925	Sandstone; grayish-red, very fine-grained, slightly calcareous, very silty, very well-sorted, flat-bedded, very homogeneous